

Potential of Natural Ventilation in Mexico According to Its Hours of Hygrothermal Comfort

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ABSTRACT

This work shows, through monthly maps, the potential of natural ventilation in order to cool down buildings in the different climatic regions of Mexico. By using the method of energy evaluation of buildings in Brazil applied to Mexico, a monthly electric-power saving factor is calculated to use natural ventilation for the forty-three biggest cities of the country according to their hours of hygrothermal comfort. Then, with the Geographical Information System Map Maker, monthly maps were created from the potentials of saving for the Mexican territory. Then, energetic, economic and environmental benefits were estimated for year 2006, in comparison to the realistic energy consumption in the same year.

Keywords: Natural Ventilation, Energy Saving Factor, Geographic Feasibility, Energy Saving

1. Introduction

The study of natural ventilation has been gradually growing during the last years because human being has known, with the right conditions, the great benefits for ventilating a building in terms of health, comfort and welfare [1]; also, there are big savings of energy and money by avoiding or by reducing mechanical ventilation and artificial systems of air-conditioning, especially in warm regions [2].

For doing good natural ventilation it needs to know climatic and atmospheric conditions of every place to analyze [3]. Also, it is necessary to do a well-done design for the building considering the needs of the occupants and the outside conditions [4].

Although the study of natural ventilation within buildings can be described for general equations [5], as every building in Mexico has particular needs of acclimatization, it was made an atlas with recommendations for buildings of the 43 main cities in the country depending on wind characteristics, climate conditions etc. [6], and that is reflected on the maps of this document. Also, in this work the potential of introducing natural ventilation as a passive system of acclimatization instead air-conditioning in Mexico has been analyzed. The geographic feasibility for that and the calculated energetic, economic and environmental benefit is shown as well.

2. Methodology

For getting the energy saving factor by using natural ven-

tilation in a building is necessary to build a mathematical model which simulates with the different elements and parameters to measure the amount of heat that is expelled by flow of air.

In this case, the mathematical model characterized from the energy saving of buildings used in Brazil was taken [7] and adapted to Mexico, and with it, an energy saving factor was calculated for different cities of Mexico in different climatic regions.

$$PT = 0.30 \cdot (ENDPI) + 0.40 \cdot \left\{ \left(ENAC \cdot \frac{AC}{AU} \right) + \left[\left(1 - \frac{AC}{AU} \right) \cdot 5 \right] \right\} + 0.30 \cdot \left\{ \left(ENCA \cdot \frac{AC}{AU} \right) + \left[\left(1 - \frac{AC}{AU} \right) \cdot 5 \right] \right\} \quad (1)$$

The second term of the Equation (1) analyzes the energetic efficiency of a building by its air-conditioning, and has a value of 40% in the complete equation. *ENAC* means the efficiency of air-conditioning within the building. The first term refers to the envelopment and it has a value of 30% in the overall evaluation, *ENDPI* is the efficiency of the envelopment according to the relationship between heat gains and heat losses by convection heat transfer. The third term refers to illumination and it has a value of 30%. *ENCA* refers to the efficiency that the artificial lights have within the building [7]. As the three terms are independent from each other, the ener-

getic efficiency by air-conditioning is separated.

$$PT_v = \left\{ \left(ENAC \cdot \frac{AC}{AU} \right) + \left[\left(1 - \frac{AC}{AU} \right) \cdot 5 \right] \right\} \quad (2)$$

In this document, two mathematical facts were found: the energetic efficiency by using natural ventilation is equal to the energy saving; and the factor denominated AC/AU , which means the relationship between the conditioned zone and the used one, is about equal to the relationship between the comfort hours and the occupied hours within a building.

$$PT_v = \left\{ \left(ENAC \cdot \frac{AC}{AU} \right) + \left[\left(1 - \frac{AC}{AU} \right) \cdot 5 \right] \right\} \quad (3)$$

$$\approx \left(1 - \frac{hc}{hu} \right) + \left[\left[1 - \left(1 - \frac{hc}{hu} \right) \right] \cdot 5 \right]$$

Therefore, an energy saving factor P_v , is found

$$P_v = \frac{\left(1 - \frac{hc}{hu} \right) + \left[\left[1 - \left(1 - \frac{hc}{hu} \right) \right] \cdot 5 \right]}{10} \quad (4)$$

Because of the climatic regions in Mexico are warm, the non-comfort hours are standardized to warm hours, which need to take out the heat somehow [8].

For a general case, the occupied hours within the buildings were the 24 hours of the day; this is that building

must be cooled (passively or actively) all day long.

Thus, P_v is multiplied by the energy consumption by air-conditioned, in kWh, then, the energy saving is found.

$$P_v \cdot [\text{consumption (kWh)}]$$

$$= \text{energy saving (kWh)} \quad (6)$$

$$\times \text{consumption with saving (kWh)}$$

$$= \text{consumption (kWh)} - \text{energy saving (kWh)}$$

3. Results

3.1. Atlas of Natural Ventilation in Mexico

With equation (4) the energy saving factors were calculated for the 43 main Mexican cities in function of their monthly comfort hours [9]. With this, maps were drawn, showing P_v in Mexico. These maps were made from the 43 vector points that represent the 43 main cities in the country, and then were drawn for their respective climatic region [10]. Regions have been clustered in three groups: with P_v from 0.10 to 0.19 (low saving), from 0.20 to 0.29 (medium saving) and from 0.30 to 0.49 (high saving).

Figures 1-12 show the geographic feasibility for the potential of introducing natural ventilation as a passive system of acclimatization instead air-conditioning in Mexico.

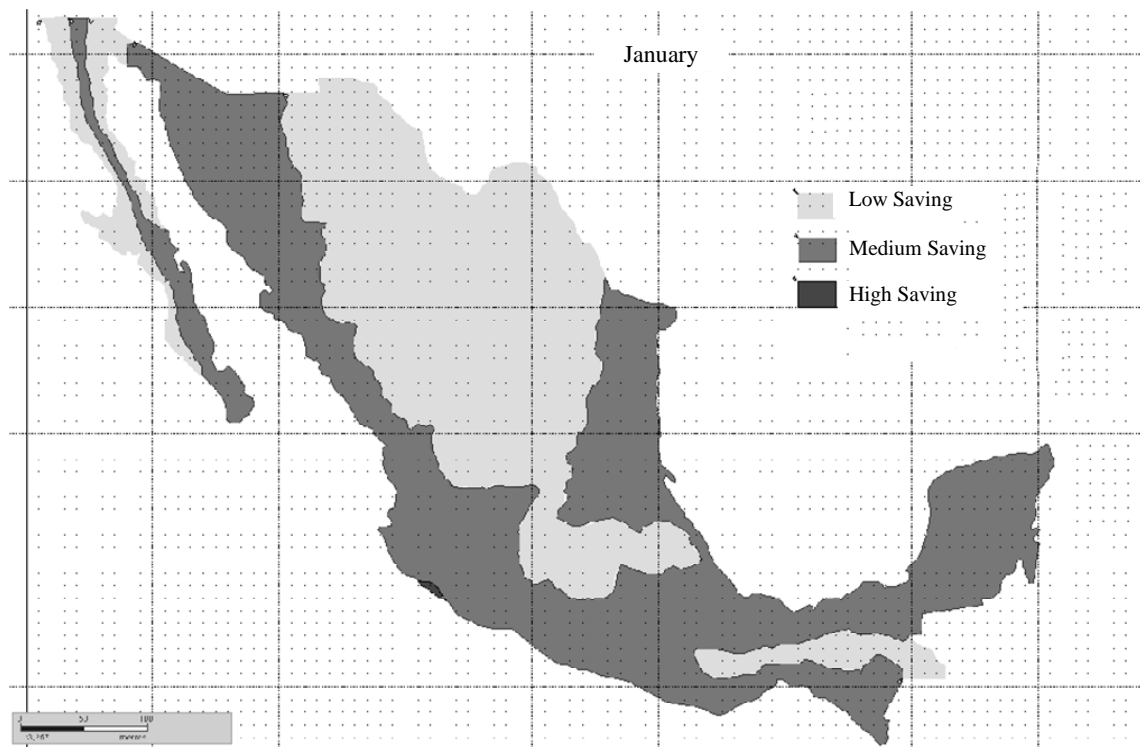


Figure 1. Saving factor, P_v for January.

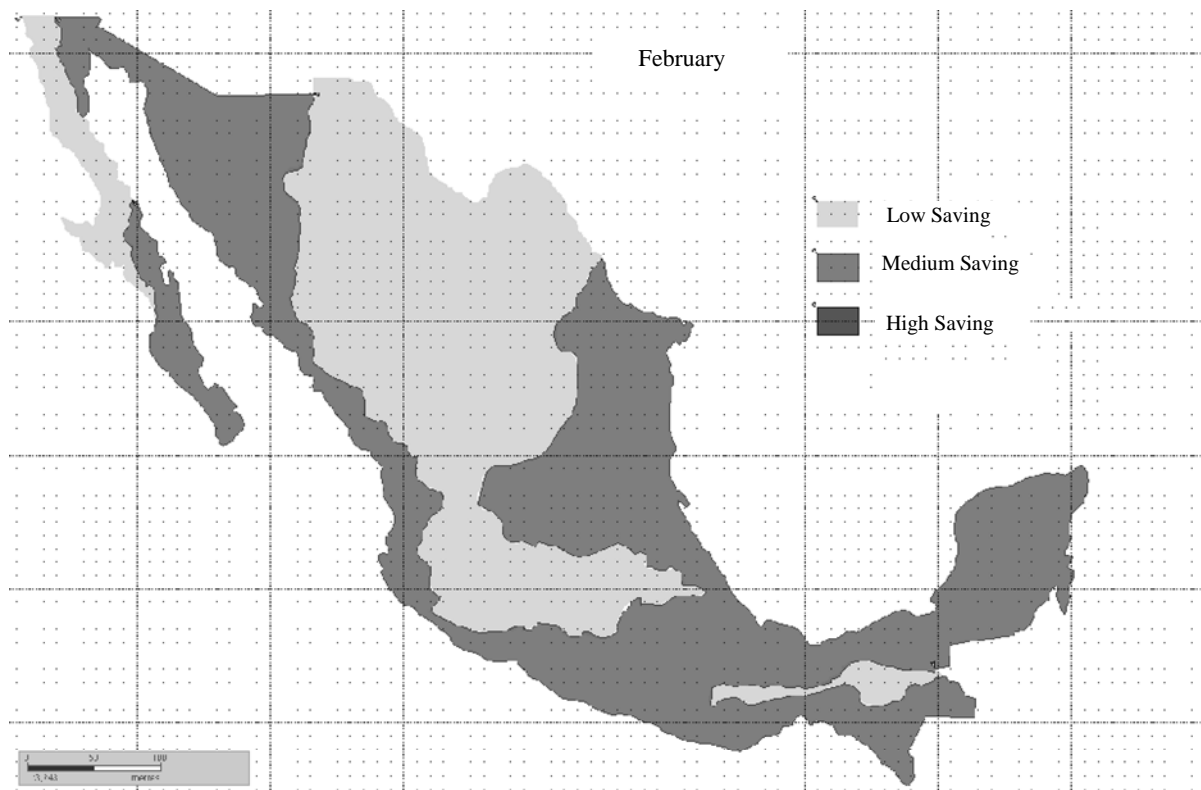


Figure 2. Saving factor, P_v for February.

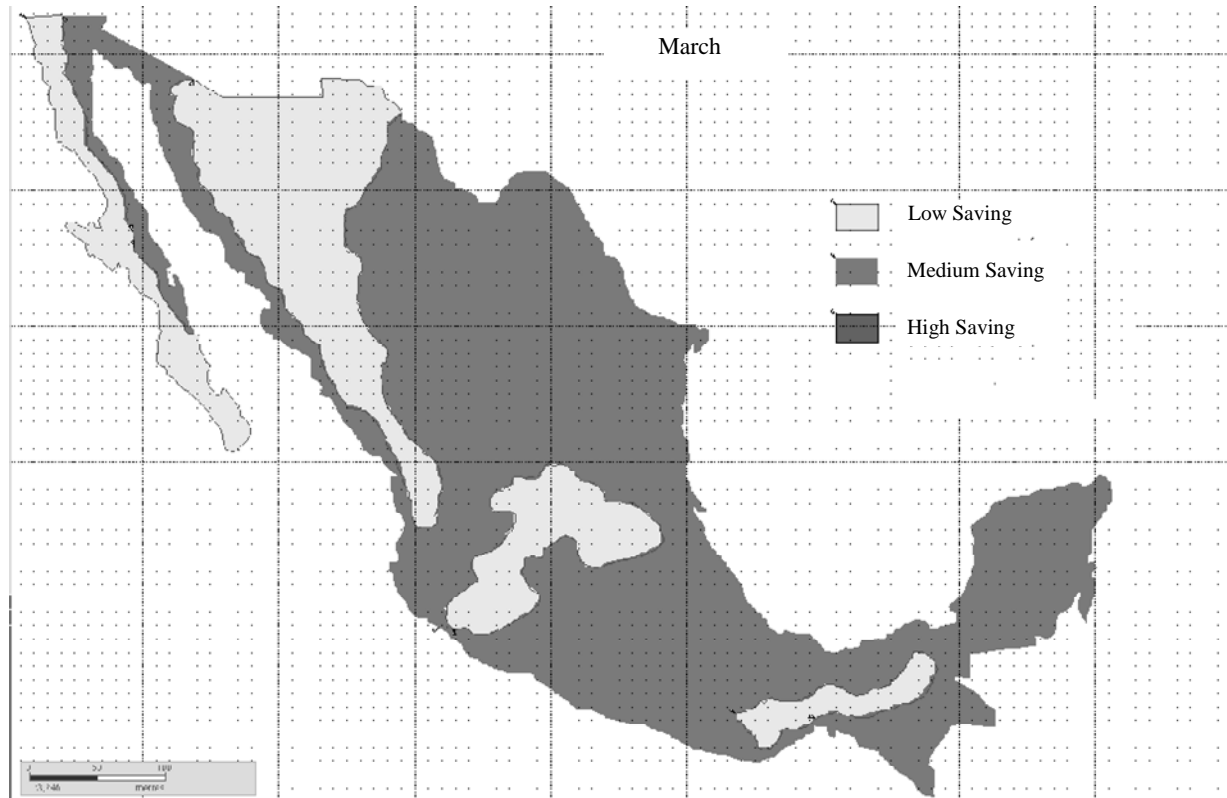


Figure 3. Saving factor, P_v for March.

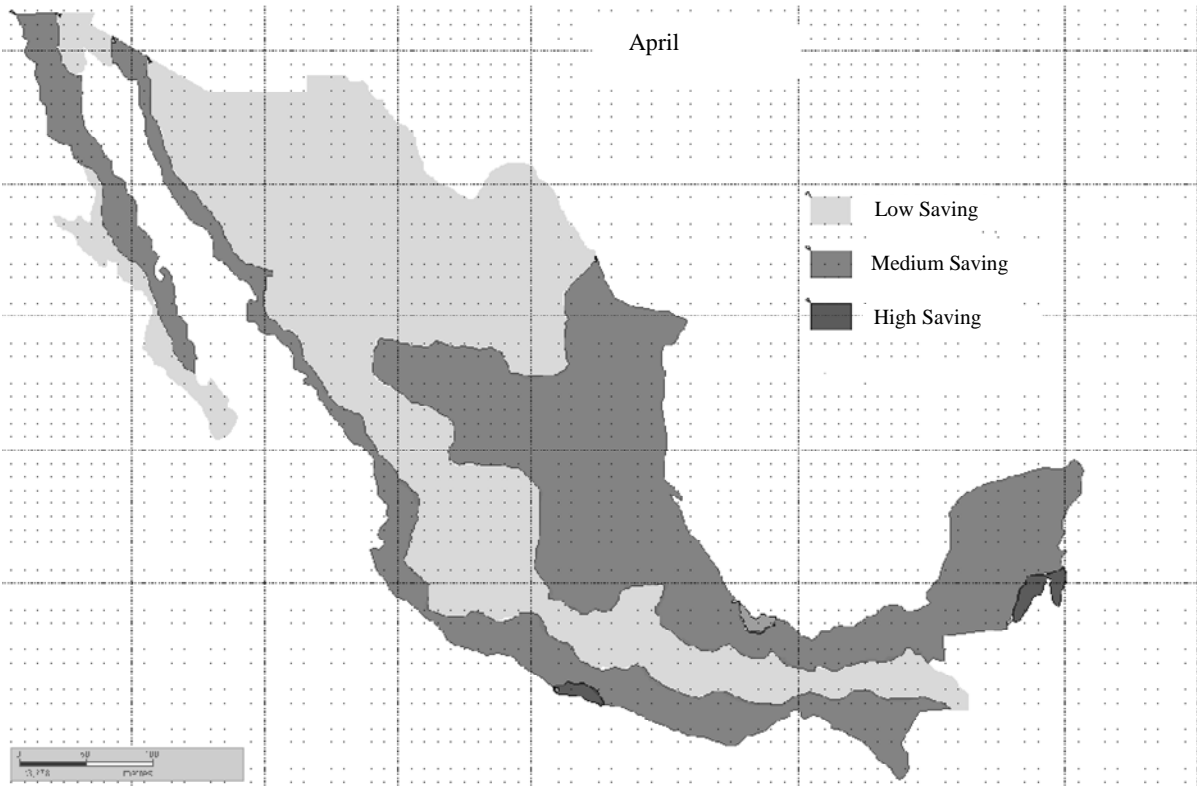


Figure 4. Saving factor, P_v , for April.

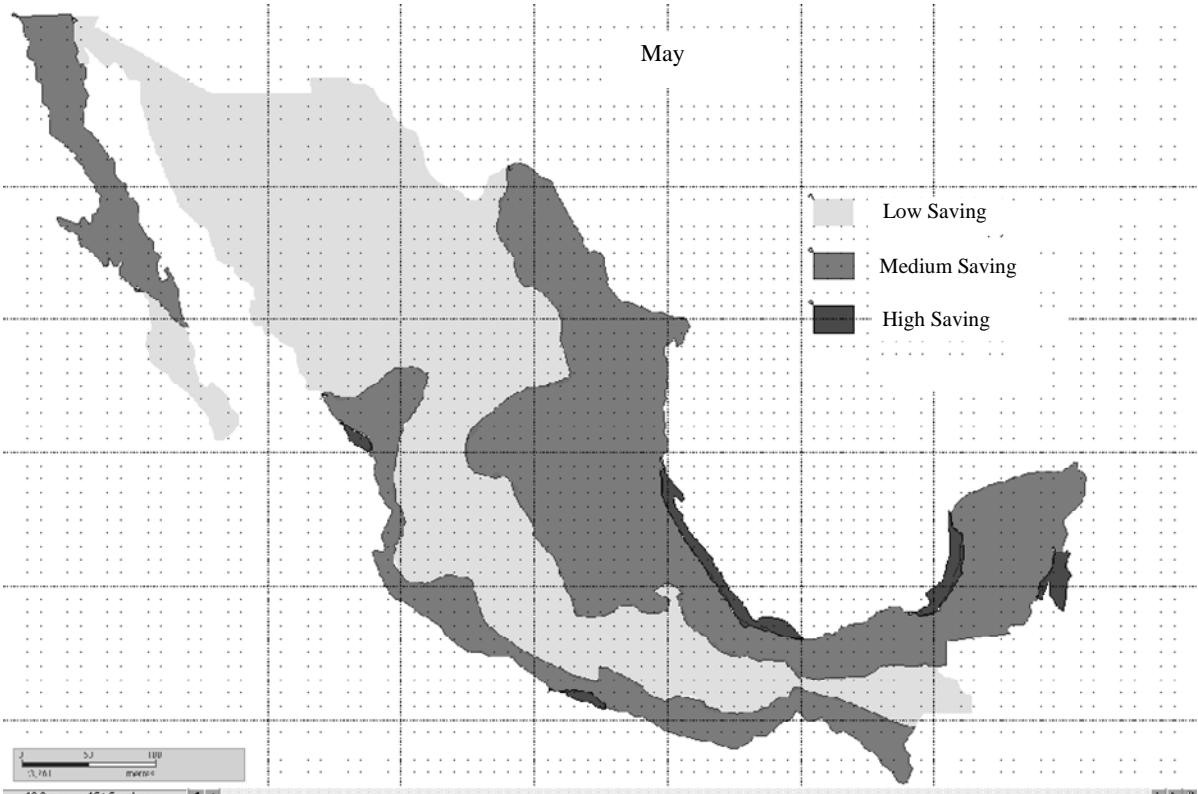


Figure 5. Saving factor, P_v , for May.

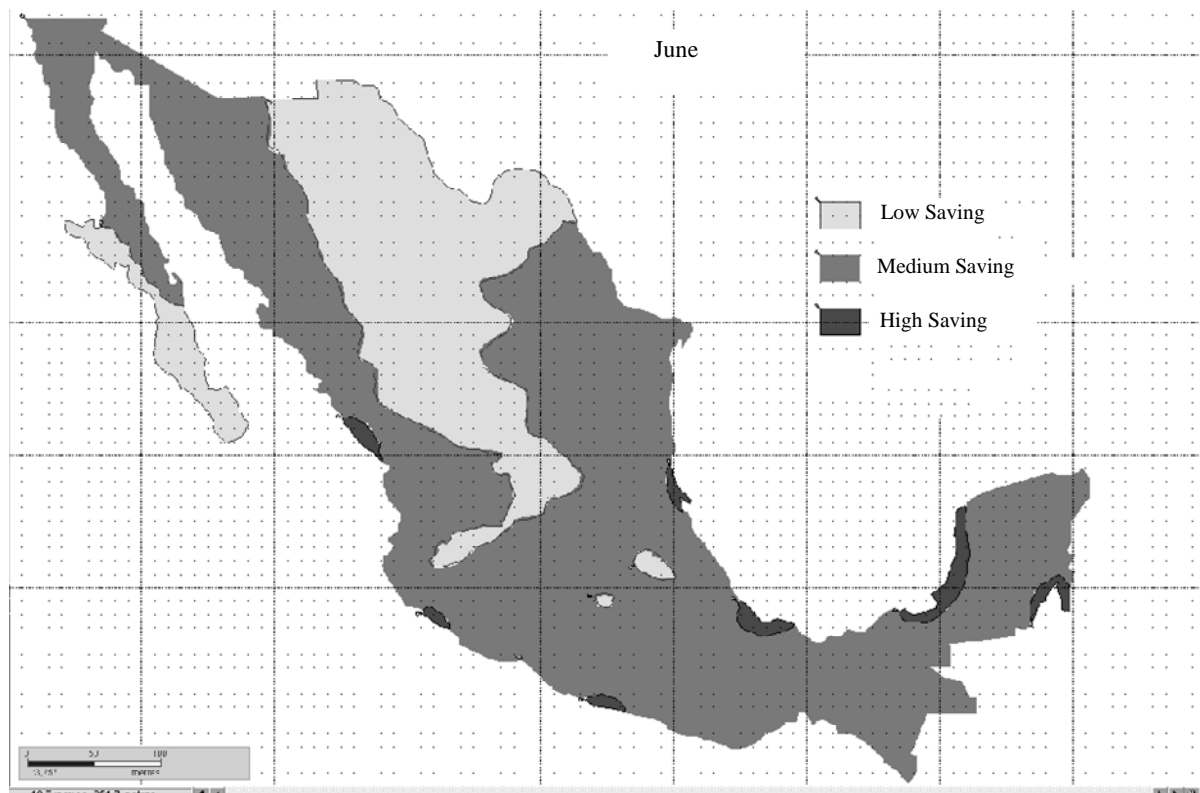


Figure 6. Saving factor, P_v , for June.

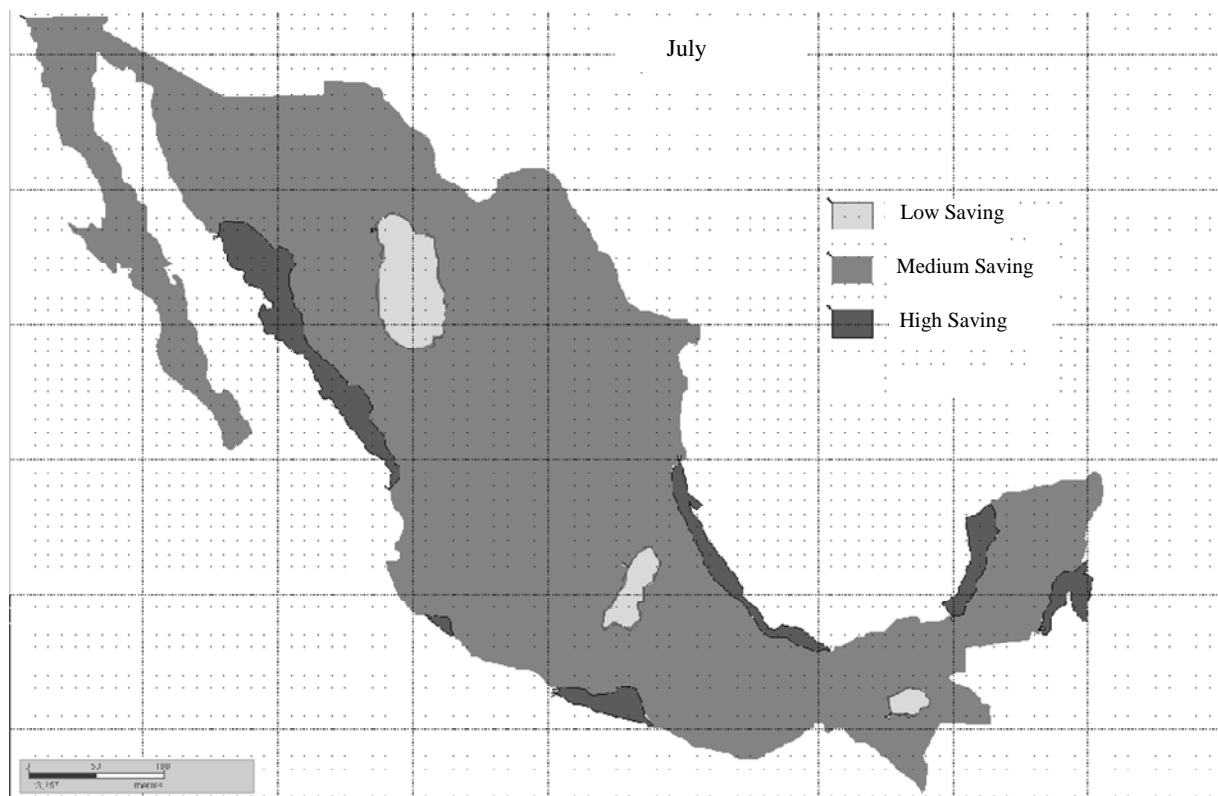


Figure 7. Saving factor, P_v , for July.

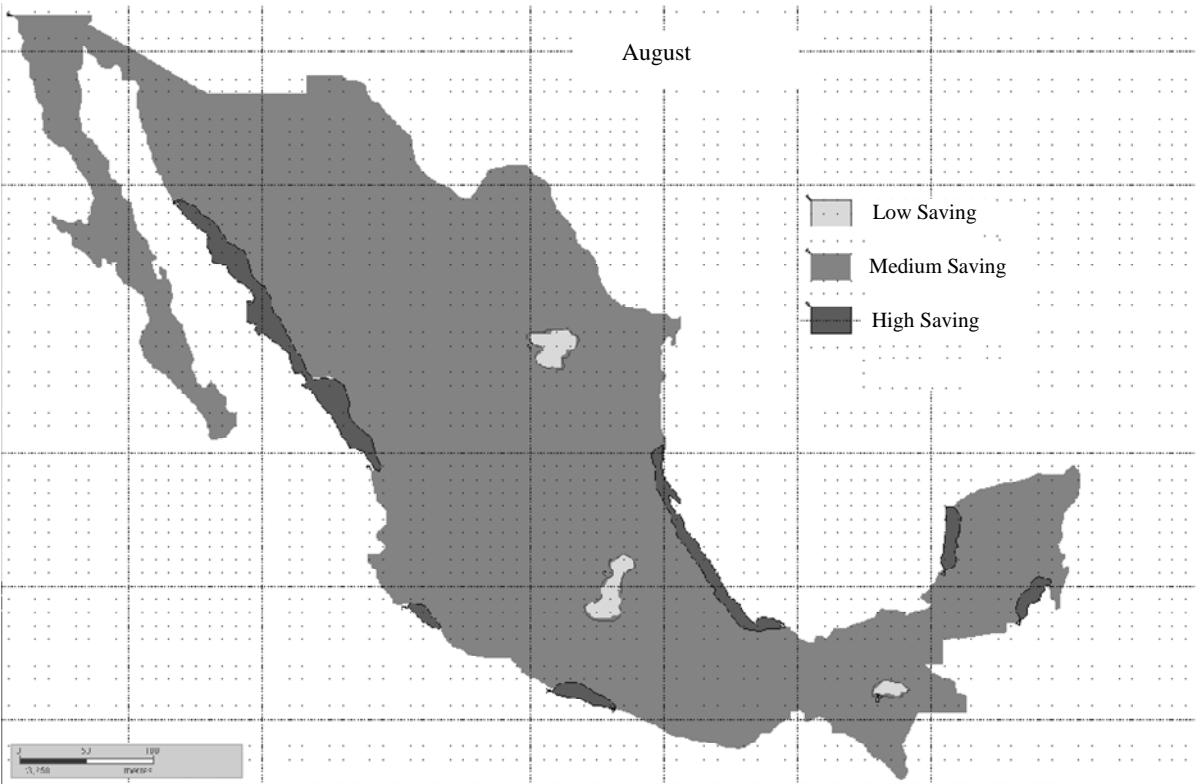


Figure 8. Saving factor, P_v for August.

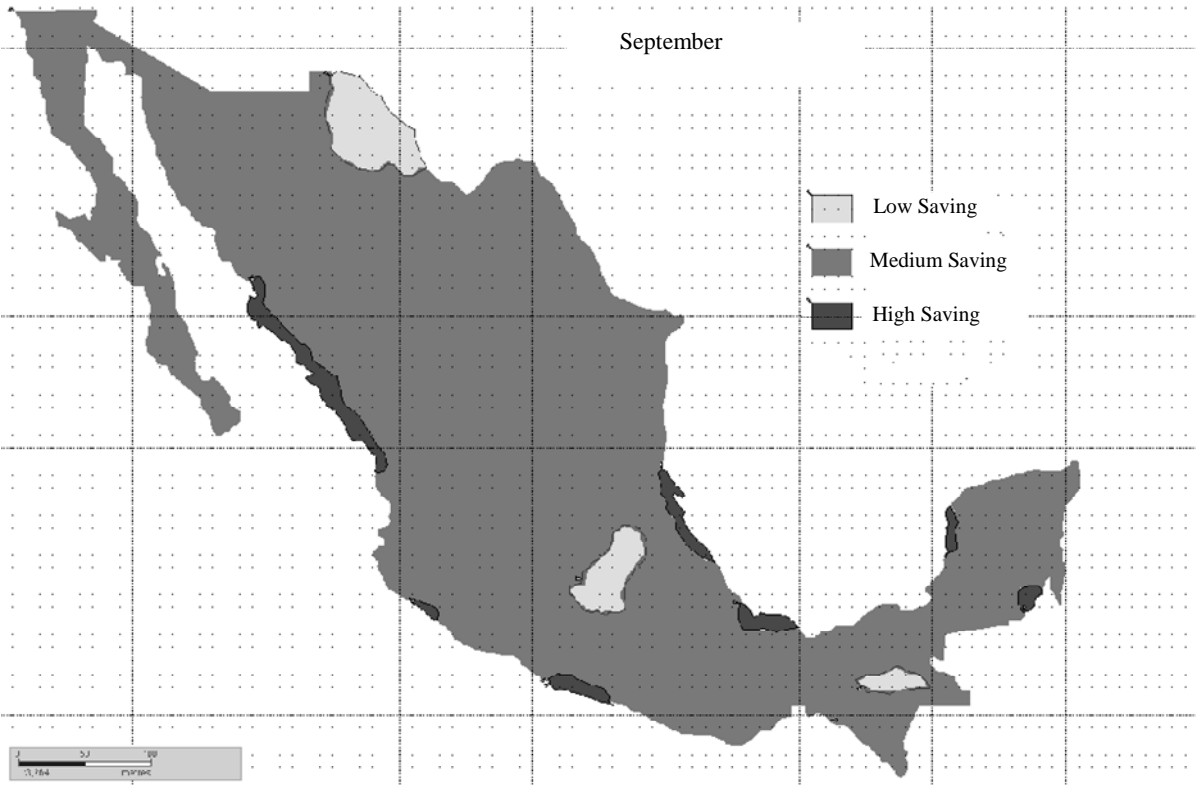


Figure 9. Saving factor, P_v for September.

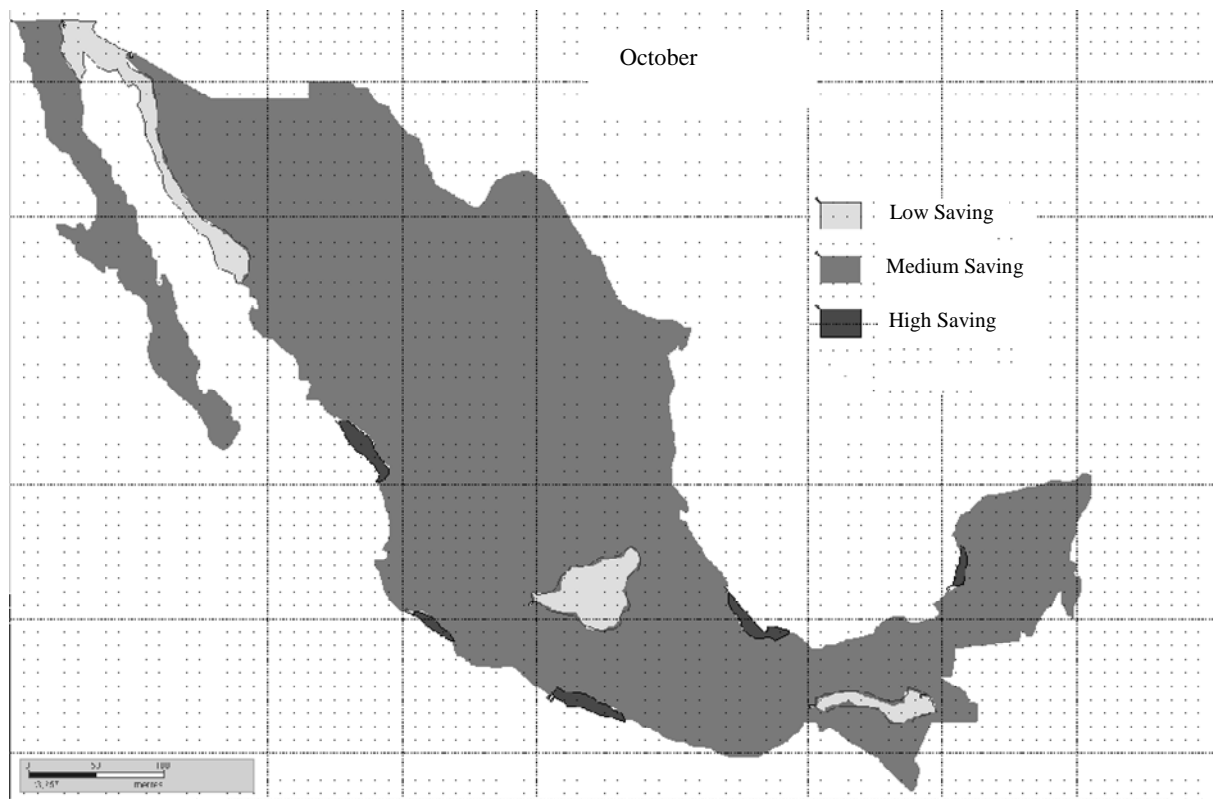


Figure 10. Saving factor, P_v for October.

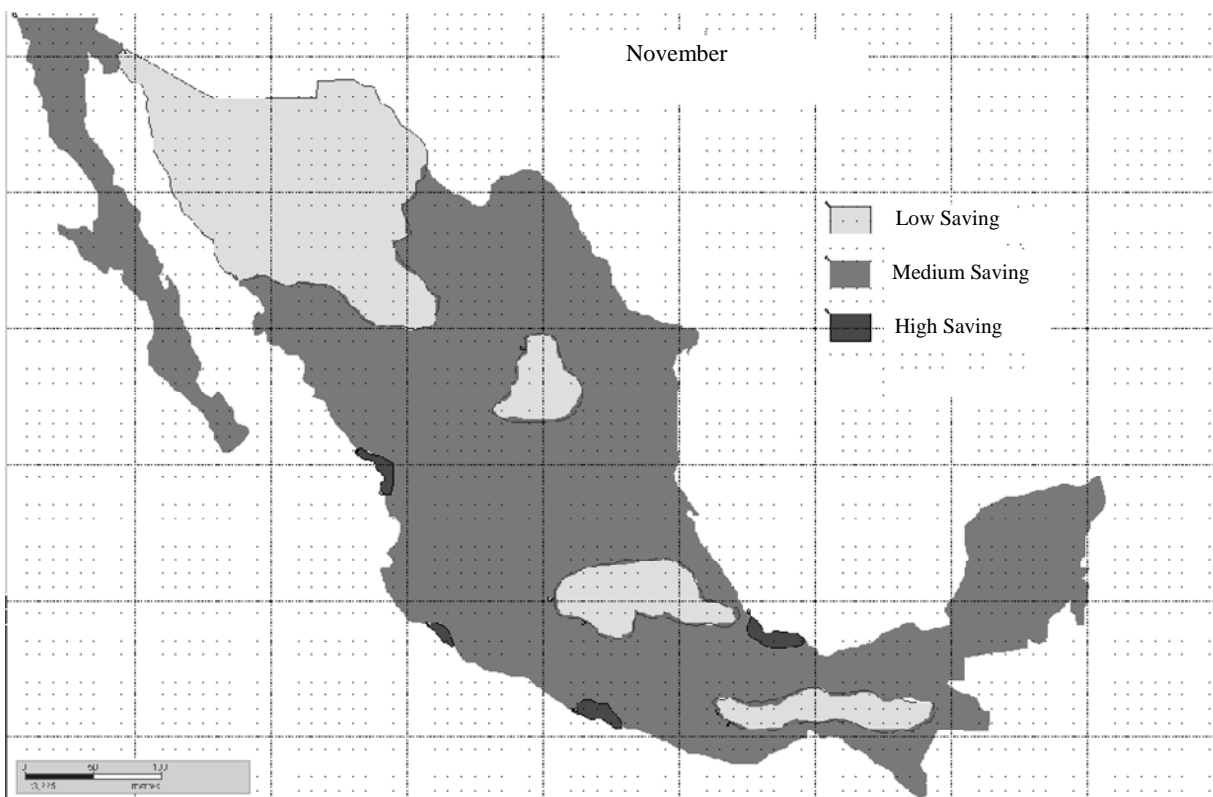


Figure 11. Saving factor, P_v for November.

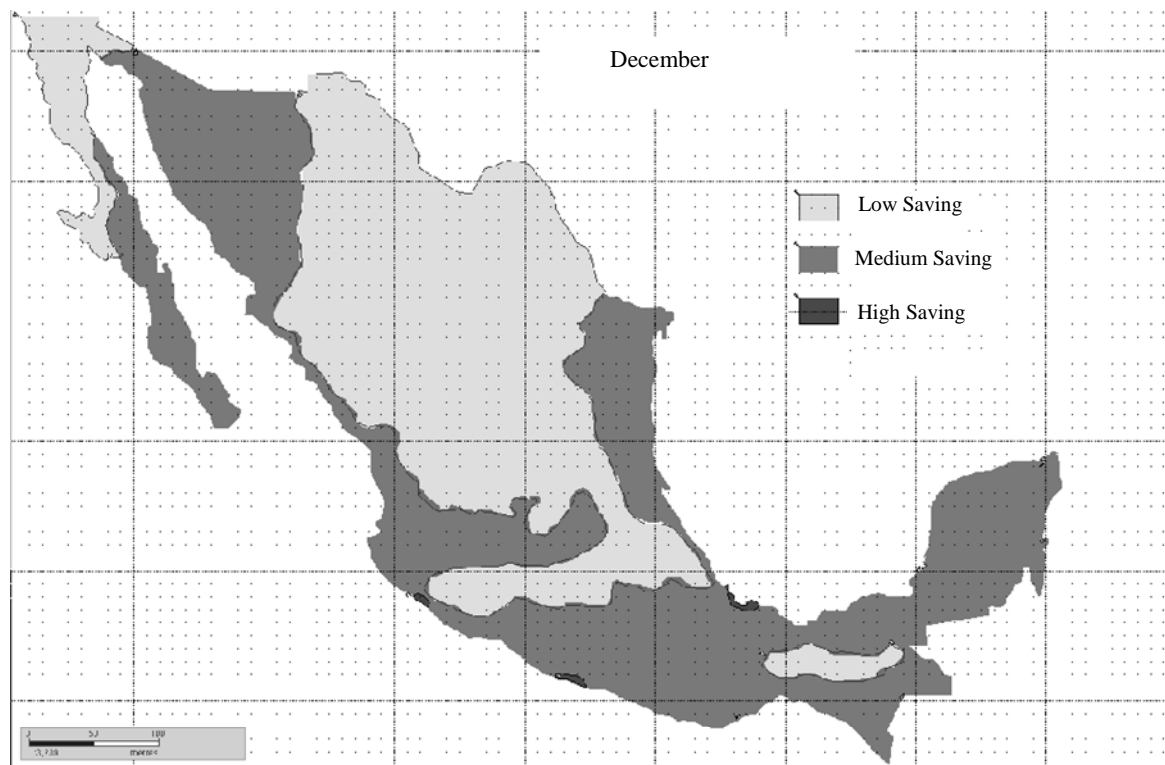


Figure 12. Saving factor, P_v for December.

4. Discussion

According to the maps shown above, all Mexican territory has a potential of saving by using natural ventilation instead using air-conditioning.

During the cool season, January, February, November and December, P_v is low, especially in the north-center part, where the climate is hot-dry. In March, April, May and June P_v increases but not so much due to high temperature and low humidity which do not help to achieve well natural ventilation. During July, August, September and October, the hot and humid season, P_v has the highest values, especially in the coasts.

Thus, statistically and according to the data tables of the energy saving factor of the cities during all year, the mean value of P_v in Mexico has a value of 0.2187.

Therefore, the energetic, economic and environmental benefits by using natural ventilation will be found by applying this mean value of P_v .

4.1. Energetic Benefits

4.1.1. Residential Sector

The average consumption of energy within a Mexican regular conditioned house gas and electricity is distributed on the following way: 44% house warming and air conditioning, 33% illumination and appliance, 14% refrigerator, and 9% water heating and stove [11].

From the 44% of house warming and air-conditioning, 8% is for house warming and 36% is for air-conditioning. But not all houses in Mexico have systems of air conditioning; from all electricity consumed in the house sector in Mexico at 2006, 17% correspond to airconditioning [11]. Therefore, the energy consumption in household sector in Mexico at 2006 was 44 452 408 MWh [12] then.

As is shown in **Table 1**, the consumption of air-conditioning in Mexico at 2006 was 7.5 TWh. Thus, the energy consumption by air-conditioning is multiplied by a general average all-over factor of energy saving.

According to **Table 2**, by using natural ventilation in households a saving of 1.65 TWh is gotten. In comparison to the Daylight Saving Time (DST) at 2006 in Mexico, which was 1.14 TWh [13], only in residential sector the energy saving is almost 1.5 times than DST.

4.1.2. Commercial Sector

By doing an analogy for commercial sector, where the

Table 1. Electric energy consumption of residential sector by air conditioning in Mexico at 2006.

Energy consumption in household sector Mexico at 2006	Percentage of consumption by air conditioning	Energy consumption by air conditioning at 2006
44,452,408 MWh	17%	7556909.36 MWh

consumption was 13,229,246 MWh, and the percentage of consumption at 2006 was 38% by air conditioning [11], the result are shown in **Table 3**.

Multiplying this consumption of 5 TWh by the average saving factor, the result is as follows

Table 4 shows that the saving was 1.09 TWh, almost the 2006 Daylight Saving Time.

4.1.3. Both Commercial and Household Sector

For both sectors, the saving is 2.75 TWh. This saving is about equal to the individual consumption of one of the Mexican states of Campeche, Colima or Nayarit [14].

4.1.4. Demand Reduction

Also, it is calculated a reduction of the maximum coincident demand of the National Electric System, in comparison to the 2006 Daylight Saving Time, which is 2265 MW, equal to three times a power plant of 750 MW [14].

4.2. Economic Benefits

4.2.1. House Sector

Considering an average price of kWh of 0.075 US Dollars [14,15] in house sector there is a saving of 131 millions US Dollars.

4.2.2. Commercial Sector

With an average price of kWh of 0.177 US Dollars [14, 15] in commercial sector there is a saving of 192 millions US Dollars.

Table 2. Energy saving by natural ventilation in the Mexican household sector at 2006.

<i>Energy consumption by air conditioning at 2006</i>	<i>Average factor of energy saving by Natural Ventilation</i>	<i>Average saving of energy in Mexican house sector at 2006</i>
7,556,909.36 MWh	0.2187	1,652,696.07 MWh

Table 3. Electric energy consumption of commercial sector by air conditioning in Mexico at 2006.

<i>Energy consumption in commercial sector Mexico at 2006</i>	<i>Percentage of consumption by air conditioning</i>	<i>Energy consumption by air conditioning at 2006</i>
13,229,246 MWh	38%	5027113.48 MWh

Table 4. Energy saving by natural ventilation in the Mexican commercial sector at 2006.

<i>Energy consumption by air conditioning at 2006</i>	<i>Average factor of energy saving by Natural Ventilation</i>	<i>Average saving of energy in Mexican commercial sector at 2006</i>
5027113.48 MWh	0.2187	1099429.71 MWh

4.2.3. National Demand

By avoiding the construction of a power plant of 750 MW, there is a saving of 1.8 billions US Dollars [14,15]. This is equivalent to avoid a power plant which generates electricity for turning on 36 millions of 60 W lamps at the same time [14].

4.3. Environmental Benefits

In Mexico, almost 75% of the generated electricity is through fossil fuels burning [12]. Therefore, application of natural ventilation could avoid the burning of 6 million barrel of oil equivalent [16] at 2006 and the emission of 1.23 million tons of CO₂ [16].

5. Conclusions

This document shows that any zone in Mexico has the option of energy saving by using natural ventilation because the model is oriented to tropical climates. As the general case was the acclimatization 24 hours at day, P_v did not pass over 0.417; but if a building has to be conditioned less hours P_v increases.

As benefits, the use of natural ventilation in household and commercial sector saves almost 0.19% of the final total consumption in Mexico at 2006. The economic benefit is the saving of 2.12 billion US Dollars in total. And the environmental benefit is the mitigation of 1.2 million tons of CO₂.

Nevertheless, implementation of massive use of natural ventilation in the whole country is not an easy task. The biggest difficulties to do that are the bad architectural designs, in energy terms, of the projected and already-built buildings; as well as the low energy efficiency behaviour of the users, among others.

Thus, the key to get these benefits is to create conscience and to show the advantage of using natural ventilation among the big actors of the country (government, constructor companies etc) to take into account designs of buildings that use natural ventilation in the projected and already-built buildings; as well as small actors (occupants, self constructors etc) who can change their behavior in order to use natural ventilation as a good way to save energy and money, also in their projected and already-built buildings.

A last comment is that this document shows the benefits that could have occurred in 2006 with natural ventilation; however, these ones have to be verified every year with the corresponding data.

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Nomenclature

h_c = Comfort hours in a month

h_u = Occupation hours in the building in a month

ENDPI = Numerical equivalent for the efficiency of envelope

ENAC = Numerical equivalent for the efficiency of air-conditioning

ENCA = Numerical equivalent for the efficiency of illumination

P_T = Efficiency level in the building

P_{Tv} = Energetic efficiency for using natural ventilation

P_v = Saving factor for using natural ventilation

AC/AU = Relationship between the areas of the conditioned zone and the used zone